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EXAMPLES OF JOINT-CONTROLLED DRAINAGE FROM WISCONSIN AND NEW YORK

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I. THE RICHLAND CENTER QUADRANGLE OF WISCONSIN

A neighboring district to the one under consideration and bordering on the upper Mississippi has been cited by Daubrée[1] as one where the influence of joints upon drainage lines has been manifested in a striking manner.

> Scattered and cuboidal blocks (bluffs and knolls) resemble ruins, deep crevasses, networks of nearly vertical valleys, of which the picturesque form strikes all of the travelers to the upper Mississippi.[1]

Farther up the Wisconsin, Van Hise has ascribed the location of the well-known Dells, or side valleys, to the position of joint planes within the underlying rocks.[2] Subsequently Buckley[3] has made an extended study of joint planes developed in the quarry rocks of the state as respects their bearings, which he has summarized as follows:

> The joints in the sedimentary rocks strike in four main directions. The prevailing general direction of the joints is northeast and southwest. The other directions are northwest and southeast, east and west, and north and south.

Inspection of Buckley's map discloses the fact that the diagonal bearings do not represent single, but several joint series.

Under the writer's direction, Mr. E. C. Harder, a member of the senior class of the University of Wisconsin, has undertaken an investigation of the joint series which are developed within the Paleozoic rock formations of southwestern Wisconsin, and has noted correspondences in orientation between the drainage lines and the joint planes. The investigation has covered districts distributed over an area comprising about 7,000 square miles in the southwestern part of the state, and has also included areas surrounding the cities of Madison and Milwaukee. In all cases the joints are in vertical series, particularly well developed in the more compact limestones. Mr. Harder's report upon the area will soon be published, and it is possible here to refer to but a single area among those examined.

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[1] *Géologie expérimentale* (Paris, 1879), Vol. I, pp. 337, 355–57.

[2] C. R. Van Hise, "The Origin of the Dells of the Wisconsin," *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters*, Vol. X (1895), pp. 556–60.

[3] E. R. Buckley, *Bulletin IV*, Wisconsin Geological and Natural History Survey, 1898, pp. 456–60.

For a considerable portion of the Richland Center Quadrangle[1] Mr. Harder's summary of the joint directions which he observed is as follows:

JOINT SERIES OCCURRING NEAR RICHLAND CENTER, WISCONSIN

N. 5° W.-1
N. 10° W.-2
N. 12° W.-2
N. 15° W.-14
N. 20° W.-3
N. 25° W.-16
N. 28° W.-3
N. 30° W.-5
N. 35° W.-23
N. 40° W.-1
N. 45° W.-14
N. 50° W.-5
N. 55° W.-23
N. 60° W.-9
N. 65° W.-9
N. 70° W.-5
N. 72° W.-2
N. 75° W.-11
N. 80° W.-4
N. 82° W.-2
N. 85° W.-5

N. and S.-7
E. and W.-11

N. 5° E.-19
N. 15° E.-5
N. 20° E.-5
N. 22° E.-2
N. 25° E.-12
N. 30° E.-2
N. 35° E.-35
N. 40° E.-1
N. 45° E.-20
N. 46° E.-2
N. 50° E.-6
N. 52° E.-1
N. 55° E.-9
N. 60° E.-5
N. 65° E.-12
N. 70° E.-5
N. 72° E.-3
N. 75° E.-24
N. 80° E.-2
N. 85° E.-9

It appears that in order of approximate numerical superiority the more important joint directions of the Richland Center district are: N. 35° E., N. 75° E., N. 55° W. (or N. 55°-65° W.), N. 85°-90° E., N. 35° W., N. 45° E., N. 5° E. (or N.-N. 5° E.), N. 25° W., N. 15° W., and N. 45° W. The tendency of the five-degree interval to appear is noticeable, and indicates that here, as elsewhere, the observations of slightly curving planes become adjusted to the larger unit of the

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[1] Surveyed, but not yet published.

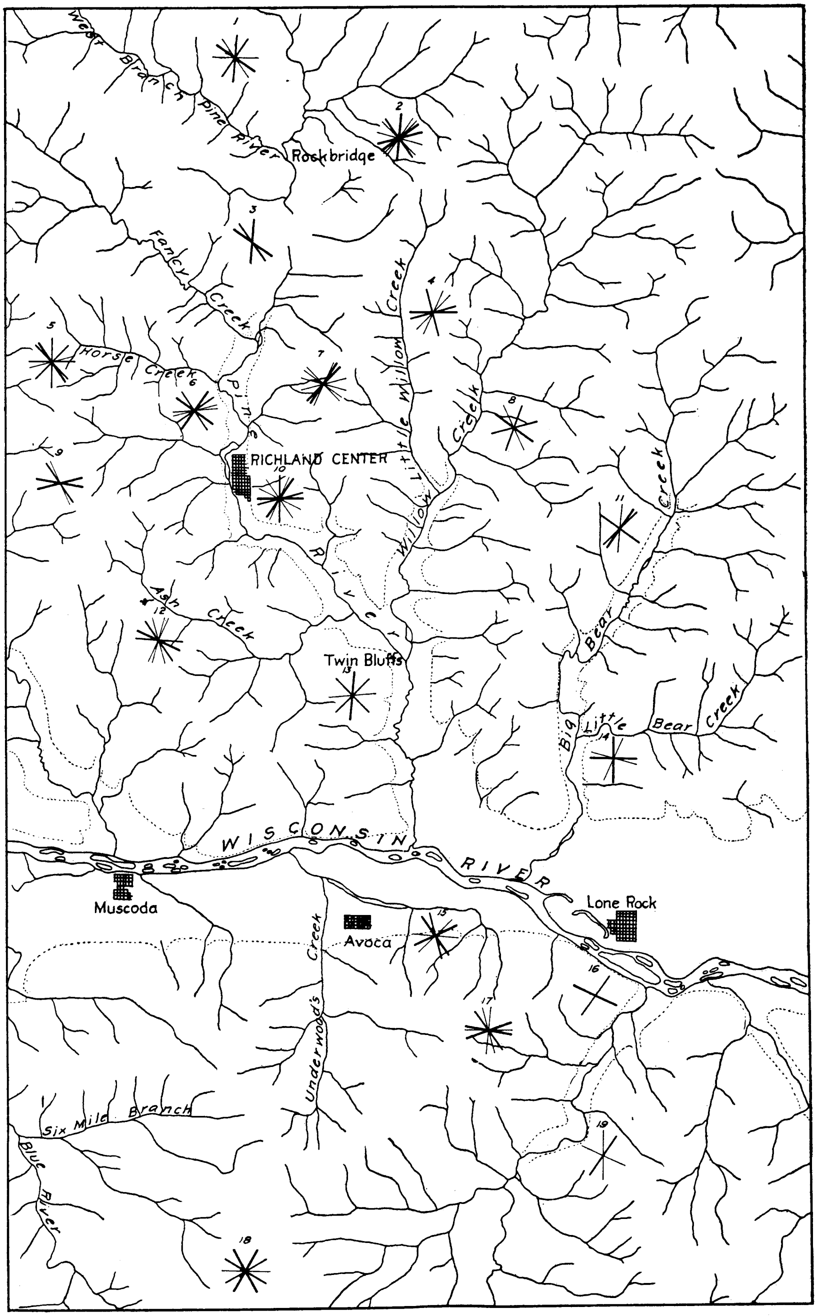

FIG. 1.—Joint and drainage map of a portion of the Richland Center Quadrangle in southwestern Wisconsin. (Prepared by Mr. E. C. Harder.) Scale, 5 miles to the inch. The dotted lines represent bluffs, while the stars indicate the local importance of joint series.

compass dial. The order of importance of the series for the local district is not quite the same as that for the larger district of which it is a part, for beyond all question the east-west direction is the predominant one. Of the entire region, also, so far as it contains ores, the mineralized crevices are mainly equatorial and meridional, less frequently "quartering" (corresponding to a diagonal series).

A glance at the map of Fig. 1 is sufficient to show that there is more than an accidental coincidence of joints and drainage systems. The map further reveals the distribution of the observations, from which distribution their relationship to near-lying drainage lines may be made out. That the correspondences were not due to mere coincidence is further attested by actual disclosures in the stream valleys where the zigzags of the course follow actual joint planes (see Fig. 2).

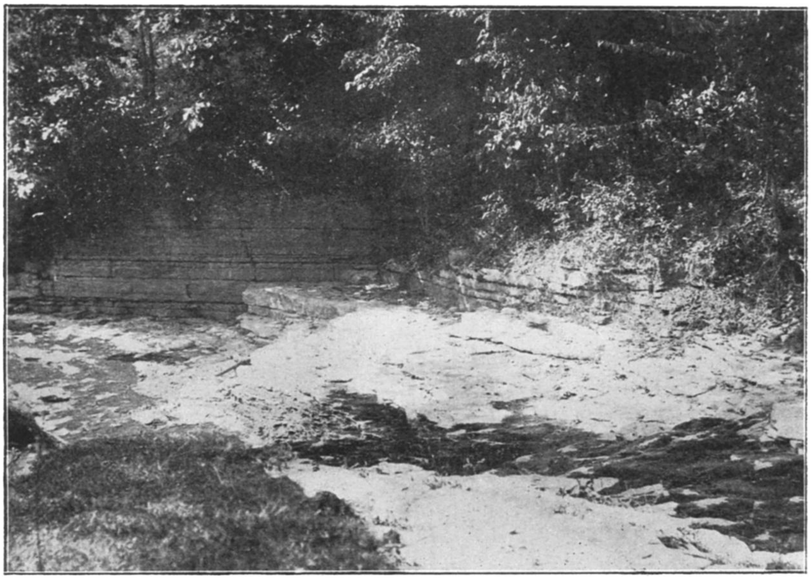

FIG. 2.—Control of direction of a stream by prevailing joint planes in southwestern Wisconsin. (Photograph by Mr. E. C. Harder.)

The Richland Center district is included within the driftless area of Wisconsin. Evidence of joint-controlled drainage is also furnished by a district lying within the glaciated area of western New York.

II. THE FINGER LAKES DISTRICT OF WESTERN NEW YORK

The Finger Lakes district has long been a classical one for the perfection of its joint planes, a cut from the locality having been used by Dana in his *Manual of Geology* as the type illustration of joint structures. Later photographs, which the writer owes to the courtesy of Professor Tarr, of Cornell University, show beyond question that the joint system has exercised an important control

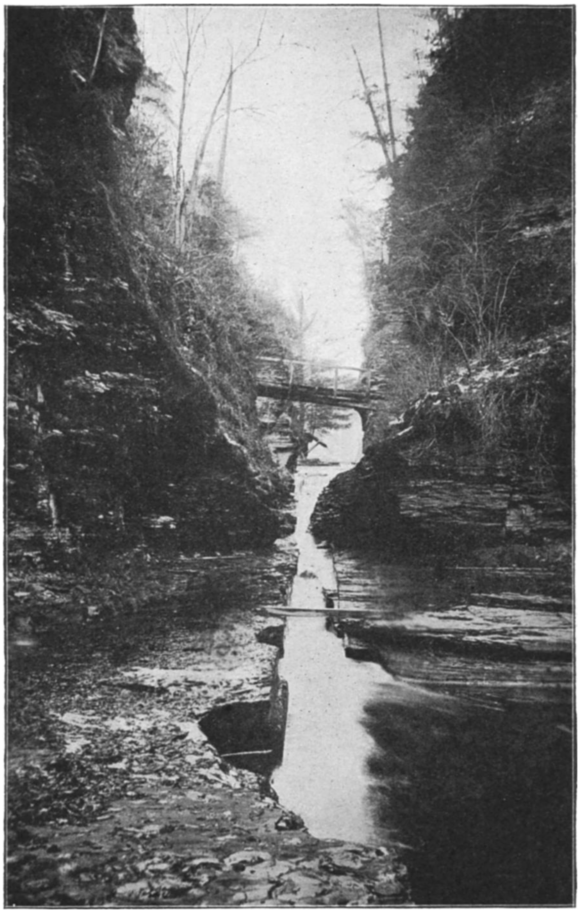

FIG. 3.—Canyon formed along a joint plane. Enfield Gorge near Ithaca, N. Y. (Photograph furnished by Professor R. S. Tarr.)

over the water courses. Striking examples of this kind are furnished by Figs. 3-5 and 4, while Fig. 5 brings out with special clearness the dominant rectangular system which is developed on the shore of Cayuga Lake.

This region about the lakes in western New York has been made the subject of many papers, owing to its topographic peculiarities and the curious distribution of the lakes themselves. Among the more important of these are papers by Lincoln,[1] Brigham,[2] Tarr,[3] and Dryer.[4]

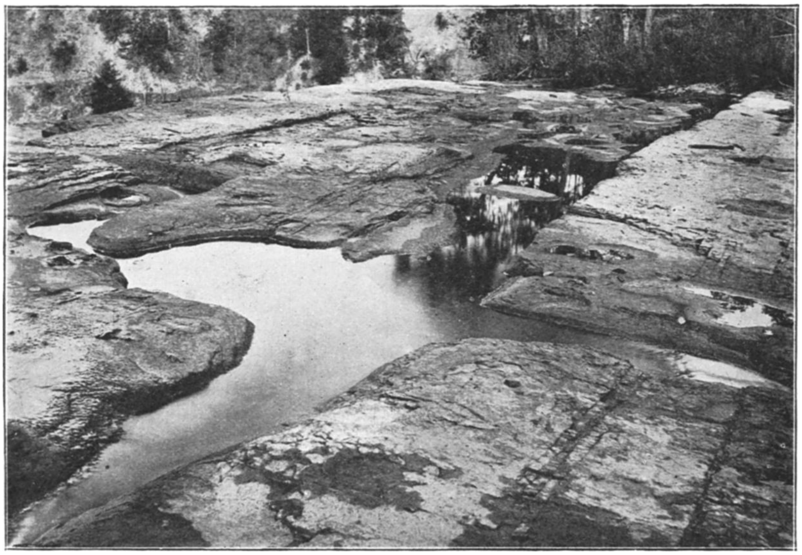

FIG. 4.—Control of direction of water course by joint planes within the basin of Cayuga Lake. (Photograph furnished by Professor R. S. Tarr.)

In these papers the peculiar topography of the lake basins is, on the one hand, ascribed to sub-aërial water erosion, and, on the other hand, to glacial erosion. At the St. Louis meeting of the Geological Society of America, held in December, 1903, the writer pointed out that, irrespective of which of the two agents had performed the major part of the work of excavating the valleys, the cause of the striking rectilinear extension of the valleys and their peculiar arrangement necessarily called for a control of whichever of the agents accomplished the work. From Professor Tarr, who was present at the meeting, it was learned that Mr. Charles G. Brown, editor of the *Holstein-Frisien World*, had undertaken the measurement of joint directions within the Cayuga Lake Basin as a thesis for graduation when a student at Cornell University. Mr. Brown has very kindly placed his results at the writer's disposal, and from a somewhat extensive survey of literature the writer is convinced that they constitute not only the most extensive, but also the most consistent, series of observations of the kind that has yet been made. This is probably in part to be explained by the perfection of the joint system within the district studied.

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[1] D. F. Lincoln, "Glaciation in the Finger Lakes Region of New York," *American Journal of Science* (3), Vol. XLIV (1892), pp. 290–301.

[2] Albert P. Brigham, "The Finger Lakes of New York," *Bulletin of the American Geographical Society*, Vol. XXV (1893), pp. 203–23.

[3] Ralph S. Tarr, "Lake Cayuga, a Rock Basin," *Bulletin of the Geological Society of America*, Vol. V (1894), pp. 339–56, Plate XIV.

[4] Charles R. Dryer, "Finger Lakes Region of Western New York," *ibid.*, Vol. XV. pp. 449–60, Plates 37–41.

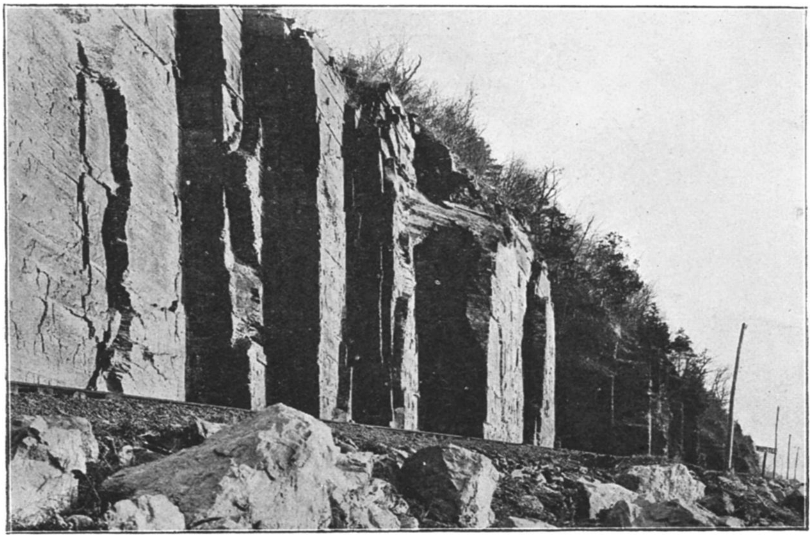

FIG. 5.—Vertical rectangular joint set on east shore of Cayuga Lake, Ithaca, N. Y. (Photograph furnished by Professor R. S. Tarr.)

Mr. Brown has measured the direction of a total of 1,004 joints, most of which are in the vicinity of Ithaca, N. Y. Some of the localities examined are Six Mile, Cascadilla, Fall, and Buttermilk Creeks; the Bates, Sheehey, Driscoll, and Veder quarries; Coy's, Shugar's, and Estey Glens; and other localities in and about Lansing, Taughannock, Portage, Genesee, and Hamilton. Another set of observations is taken from the Cayuga Creek gorge, Havana and Watkins Glens, the west shore of Seneca Lake, and localities about Norwich. The results of this investigation are not published, but through the courtesy of Mr. Brown I am permitted to make use of his results in this article. After a careful enumeration of the joint directions observed, Mr. Brown says in his thesis:

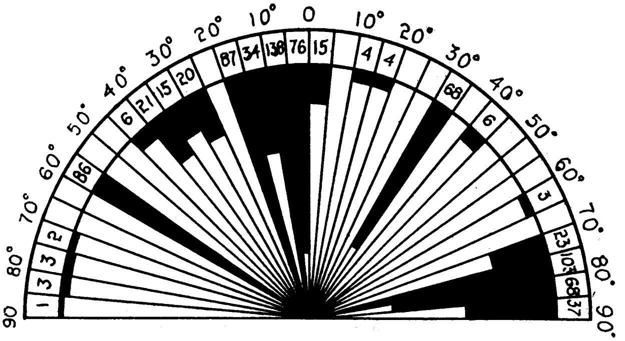

FIG. 6.—Diagram to show the orientation of joints in the Cayuga Lake basin of western New York (Brown).

> The correlation presented in Fig. 4 seems to indicate that these joints constitute two orthogonal systems. Those whose direction trend N. and N. 45 degrees W., and N. 70 degrees E. and E., constituting the major system; while those whose direction trend between N. and N. 20 degrees E., and N. 70 degrees W. and W., constitute the minor system. It will also be seen that the major system contains 551 of the 572 joints correlated,[1] or 96 per cent. of the whole number; while 374, or 67 per cent., of those constituting the major system lie between N. and N. 45 degrees W.

Mr. Brown's results covering this area I have brought together below in a single table, in order to show their orientation as respects the entire area:

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[1] This does not include the later work.

N. 2° W.	1		N.-S. 15	N. 4° E.	1	
N. 4° W.	**30**					
N. 5° W.	**6**	**43**		N. 5° E.	1	
N. 6° W.	**7**			**N. 10° E.**	**2**	
N. 8° W.	2			N. 12° E.	2	
N. 10° W.		**139**		N. 16° E.	4	
N. 12° W.	14			N. 20° E.	2	
N. 15° W.	**54**	**88**				
N. 16° W.	**34**			**N. 30° E.**		**68**
N. 18° W.	4			N. 45° E.	6	
N. 20° W.		**288**		N. 60° E.		**3**
N. 24° W.	5					
N. 26° W.	1					
N. 30° W.	**20**	**35**				
N. 34° W.	**15**			**N. 70° E.**	**21**	
N. 40° W.		**51**		**N. 72° E.**	**8**	
N. 44° W.	6			**N. 74° E.**	**90**	**131**
N. 60° W.		**86**		**N. 75° E.**	**12**	
N. 74° W.	1			N. 78° E.	1	
N. 76° W.	1			**N. 80° E.**		**62**
N. 80° W.	3			**N. 85° E.**		**35**
N. 84° W.	1		E.-W. 1	N. 88° E.	2	

Making use of five-degree intervals the above results are graphically summarized in Fig. 6.

In order of relative numerical importance the joint directions of the district are thus found to be: N. 20° W. (288), N. 10° W. (139), N. 70°–75° E. (131), N. 15°–16° W. (88), N. 60° W. (86), N. 30° E. (68), N. 80° E. (62), N. 40° W. (51), N. 4°–6° W. (43), N. 30°–34° W. (35), N. 85° E. (35), and N.–S. (15). These twelve directions include 941 of the 1,004 measurements, and, with the exception of the directions N. 12° W., whose fourteen observations should perhaps be added to the 139 directed N. 10° W., no other direction is represented by more than six measurements.

From the above figure it will also appear that there is an orthogonal joint set having directions N. 30° E., and N. 60° W. There are also two other near-lying orthogonal sets, the one having direction N. 74°–75° E. and N. 10°–16° W., and the other N. 80°–85° E. and N. 4°–6° W. In the vicinity of Watkins Glen, the first-mentioned set is the dominant one, while at the other localities this set is rarely observed, the other sets taking its place.

These data collected by Mr. Brown make it possible to see whether any correspondences exist between the dominant hydrographic lines of the district and the underlying fracture system. A map of the district based on the one prepared by the College of Engineering of Cornell University is reproduced in Fig. 7.

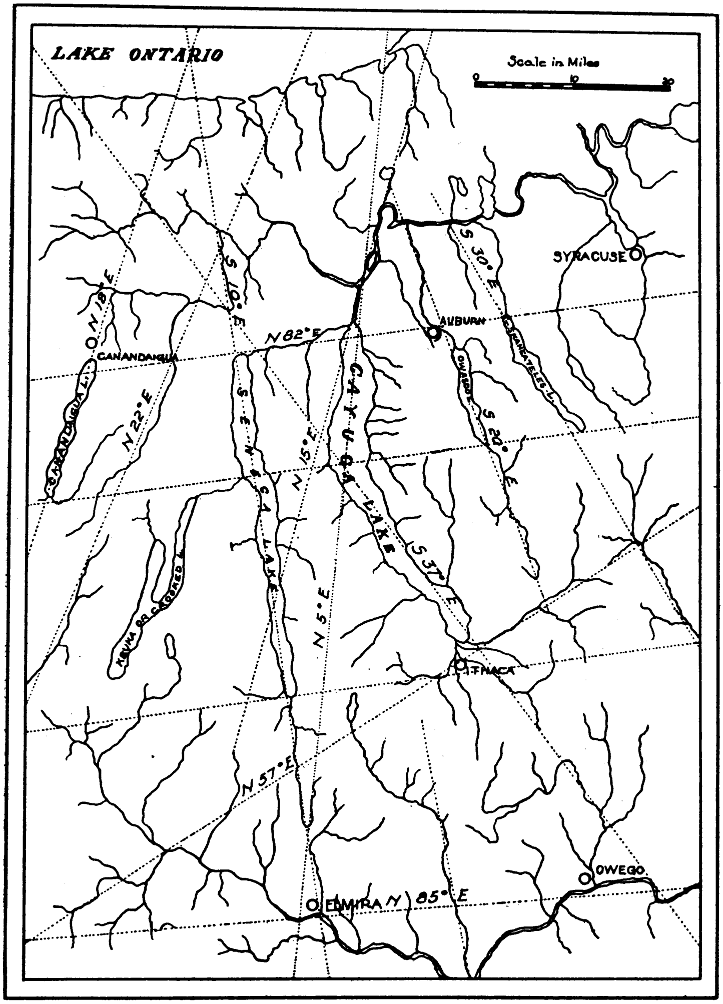

FIG. 7.—Map of the Finger Lake region of western New York, with indication of the more striking hydrographic lines.

The most striking hydrographic line of the district may be called the Seneca line, which is directed about N. 10° W., and which for a distance of nearly 60 miles is outlined in part by Seneca Lake itself, to the south by an open valley which extends as far as Elmira, and to the north by a reach of Canandaigua Outlet. Three lineaments, nearly parallel, are directed in a nearly perpendicular direction to the Seneca line, and may be designated respectively as the Seneca Falls line, the Penn Yan line, and the Watkins Glen line. For a portion of their extent these lines correspond to the boundaries of formations, and the fact that they are fall lines is thus in part explained. Their alignment, however, is no less significant, since the joint planes have so largely determined the areal limitation of the formations. The line of Owasco Lake is directed N. 20° W., and may be followed in the drainage for a distance of about 40 miles. The line of Skaneateles Lake and Tioughnioga River together make a prominent lineament directed N. 30° W., and followed for a distance of about 40 miles. Upper Cayuga Lake and its extension in drainage lines to the northwestward and southeastward mark out a lineament whose direction is N. 37° W., and which may be followed for some 70 miles. Less striking lineaments are directed along Canandaigua Lake (N. 18° E.), Cayuga Outlet (N. 15° E.), and along Flint and Twelve Mile Creeks (N. 22° E.).

Comparing, now, these lineaments with the joints observed by Mr. Brown, we have:

Lineament and its Bearings	Approximate Length Indicated	Number and Bearing of Joints Observed by Mr. Brown
Seneca line (N. 10° W.)...................	60 miles	139 (N. 10° W.)
Owasco line (N. 20° W.)..................	40 miles	288 (N. 20° W.)
Upper Cayuga line (N. 37° W.)...........	70 miles	66 { 51 (N. 40° W.) 15 (N. 34° W.)
Skaneateles line (N. 30° W.)..............	40 miles	35 (N. 30° W.)
Seneca Falls line (N. 82° E.)..............	40 miles	97 62 (N. 80° E.) 35 (N. 85° E.)
Penn Yan line (N. 82° E.).................	40 miles	
Watkins Glen line (N. 82° E.)............	20 miles	
Cayuga Outlet line (N. 15° E.)...........	20 miles }	4 (N. 16° E.)
Canandaigua line (N. 18° E.).............	15 miles }	

The directions of the Seneca, Owasco, Upper Cayuga, and Seneca Falls lines are respectively those of the second and first in relative numerical importance among the joints observed in the district, as will be seen by comparing with the table on p. 371. The Skaneateles line is also along one of the most prominent directions of jointing. Of the less strongly indicated directions (Canandaigua line and Flint and Twelve Mile Creeks line, N. 18°–22° E.) no strong indication of control by jointing is observable, though the direction N. 16° E. is that of four observed joints, whereas no other directions between N.–S. and N. 30° E. have more than two representatives among those recorded.